

1

2,828,232

METHOD FOR PRODUCING JUNCTIONS IN SEMI-CONDUCTOR DEVICE

Jon H. Myer, Culver City, Calif., assignor to Hughes Aircraft Company, Culver City, Calif., a corporation of Delaware

Application May 1, 1956, Serial No. 581,941

16 Claims. (Cl. 148—1.5)

This invention relates to fused junction semiconductor devices and more particularly to new methods for producing the same.

In the semiconductor art, a region of semiconductor material containing an excess of donor impurities and having an excess of free electrons is considered to be an N-type region, while a P-type region is one containing an excess of acceptor impurities resulting in a deficit of electrons or, stated differently, an excess of holes. When a continuous solid specimen of semiconductor material has an N-type region adjacent a P-type region the boundary between them is termed a P-N (or N-P) junction, and the specimen of semiconductor material is termed a P-N junction semiconductor device. Such a P-N junction device may be used as a rectifier, photocell, transistor, or the like. A specimen having two N-type regions separated by a P-type region, for example, is termed an N-P-N junction semiconductor device or transistor, while a specimen having two P-type regions separated by an N-type region is termed a P-N-P junction semiconductor device or transistor.

These P-N or N-P junctions are hereinafter referred to as rectifying junctions or simply as junctions. It often is desirable to provide a non-rectifying junction or ohmic contact to a semiconductor device. The method of the present invention is peculiarly adapted to the production of both rectifying and non-rectifying junctions by the phenomenon of diffusion of active impurity atoms into the semiconductor starting crystal. When a P-type starting crystal of a given resistivity, for example, has diffused therein, acceptor atoms, a diffused P-type region of a different resistivity is produced. The interface between these two regions is what has been herein termed a non-rectifying junction or ohmic contact. The term junction, therefore, for the purpose of this invention is intended to include both rectifying and non-rectifying junctions.

The term semiconductor material as utilized herein is considered generic to both germanium and silicon, and is employed to distinguish these semiconductors from metallic oxide semiconductors such as copper oxide and other semiconductors consisting essentially of chemical compounds.

The term "active impurity" is used to denote both impurities which affect the electrical rectification characteristics of semiconductor material as distinguished from other impurities which have no appreciable effect upon these characteristics. Active impurities are ordinarily classified as donor impurities such as, phosphorus, arsenic, and antimony, or acceptor impurities such as boron, aluminum, gallium, and indium.

In the prior art P-N junction semiconductor devices have been produced by fusing small amounts of a low melting-point acceptor impurity with portions of a semiconductor starting specimen. According to this prior method, a predetermined amount of low melting-point acceptor impurity such as indium, for example, is placed in contact with the surface of an N-type germanium

2

specimen. The specimen and the contacting indium are then heated to a temperature above the melting point of the indium, but below the melting point of the germanium specimen in order to melt the indium and dissolve therein a portion of the adjacent germanium. The specimen is then cooled so that the dissolved atoms of germanium and indium are regrown onto the specimen thereby producing an indium-saturated P-type region in the semiconductor specimen.

It has been recognized in the semiconductor art for sometime that silicon has many physical advantages over germanium, in particular its ability to withstand relatively high operating temperatures. Nevertheless, fused-junction silicon diodes or transistors have been difficult to produce heretofore owing to the fact that the production techniques which have been found suitable for producing fused-junction germanium devices are not adaptable to the production of fused-junction silicon devices. More particularly, the production of fused-junction silicon devices has been complicated by several basic factors. First, it is difficult to make a good ohmic electrical connection to silicon. The more conventional techniques employed for connecting to germanium have been found to produce with silicon relatively high impedance connections which in many instances are asymmetrically conductive. Second, the inherent tendency of silicon toward rapid formation of extremely hard and stable oxide has rendered it difficult to create fused-junction silicon devices because of the inability of the active impurity employed in the fusion process to wet the adjacent surface of the silicon. Accordingly, in the hereinabove described methods for producing a fused junction in a semiconductor starting crystal, and more particularly in a silicon semiconductor starting crystal, it is typically required that a non-oxidizing or inert atmosphere be provided in the immediate vicinity of the junction area.

Another disadvantage inherent in the method above referred to is that only relative small area junctions may so be produced.

The present invention overcomes the above and other difficulties which have heretofore limited the use of silicon and often germanium and provides diffused-junction silicon and germanium semiconductor devices which have exceptional electrical characteristics.

According to the basic concept of the present invention methods are disclosed for producing a non-rectifying low-impedance electrical connection to a silicon or germanium starting specimen and also for creating rectifying junctions within the specimen by fusing thereto a salt containing an active impurity which is capable of readily wetting silicon or germanium and act as a source of the active impurity to be diffused into the specimen.

More particularly, according to a preferred embodiment of the invention a diffused junction silicon device is produced by immersing a silicon starting wafer of N-type conductivity in a salt containing as one of its elements an acceptor impurity such as boron, and heating the crystal-salt combination to a temperature above the melting point of the salt, but below the melting point of the crystal and below the decomposition temperature of said salt. In addition the present invention provides methods for creating an ohmic contact to a P-type semiconductor starting crystal.

Accordingly, it is an object of the present invention to provide a new method for producing large-area junction semiconductor devices.

A further object of the present invention is to provide a method for diffusing an active impurity into a semiconductor starting crystal without the necessity of using an inert ambient.

A still further object of the invention is to provide